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ORGDP URANIUM DISCHARGES

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Oak Ridge Gaseous Diffusion Plant
Operated by Martin Marietta Energy Systems, Incorporated
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#53

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Purpose

The purpose of this report is to tabulate the quantities of uranium released from the Oak Ridge Gaseous Diffusion Plant (ORGDP) and to discuss the associated health impacts. The report only considers uranium. Data on other radionuclides, such as technetium, will be released at a later date. Material from airborne releases, liquid effluent releases, and solid waste generation has been considered.

Summary

This report provides the quantities of uranium released from ORGDP and the available data on uranium concentrations in the environment. Since 1946, a total of 15.6 curies of radioactivity have been released into the air, 14.3 into water, and 33.7 buried in solid waste. Concentrations in air and water have been well below applicable guidelines. A calculation of potential health effects (fatal cancers) shows that about 0.14 is expected to occur. It is unlikely that this effect has or will occur as a result of these releases. Appendixes A and B discuss the implications of these results and the regulatory guidelines, respectively.

Introduction and History

ORGDP is a complex of production, research and development, and support facilities located west of the city of Oak Ridge. The primary function of ORGDP is the enrichment of uranium hexafluoride in the uranium-235 isotope, by gaseous diffusion process, for subsequent production of nuclear reactor fuel. Extensive research and development efforts have been expended on both the gaseous diffusion and centrifuge processes. Other activities include facilities for maintenance, laboratories, decontamination, recovery of uranium, etc.

Associated with the uranium handling and processing activities at ORGDP have been waste disposal operations (primarily shallow land burial) and releases to the atmosphere and adjacent streams. In general, the quantities of uranium released were and continue to vary with the types of operations employed, the level of activity associated with production, and the types of emission controls utilized. The control of airborne and liquid releases has, for the most part, improved through the years as have the capabilities for monitoring releases and evaluating environmental consequences with the greatest improvements having been realized since 1971. Included in Tables 1, 2, and 3 are the available information on the release and disposal of uranium from ORGDP.

At ORGDP, the primary sources of airborne uranium emissions have been and are now the gaseous diffusion process vent (purge cascade), associated UF_6 handling operations, and uranium decontamination and recovery operations. Prior to 1964, ORGDP was involved in the enrichment to high assays (greater than 90 percent U-235) of uranium (as UF_6) for weapons production, and

subsequent to 1964 only low assay (less that 5 percent U-235) enrichment has been done. In addition, a UF_6 production facility was operated from 1950 to 1968 constituting a major source of uranium emissions for that time period as reflected in Table 1. Of considerable importance in reviewing ORGDP release information is the fact that the largest quantities of uranium were released to the atmosphere in the early years (prior to 1976) through unplanned discharges. In general, any annual airborne emission value in excess of 20 kg can be considered a result of unplanned releases. New and improved emissions control systems have been installed on the various routine sources consisting of particulate filters, solid chemical trapping systems, and a liquid potassium hydroxide scrubber which was installed on the purge cascade vent in 1977.

Primary liquid effluent releases of uranium from ORGDP have historically resulted from uranium decontamination operations, with recovery and recycle being the major emission control mechanism. Liquid wastes discharged from the recovery operation are passed through a settling pond where insoluble uranium compounds are removed and retained onsite. The liquid effluent then discharges to Poplar Creek which flows into the Clinch River (See Map Number 4). Uranium releases from liquid effluents are reflected in Table 2.

Solid wastes containing uranium generally include: waste paper, rags, and floor sweepings from general cleanup operations; wastewater treatment sludges; airborne effluent treatment residuals such as filter and trapping media, scrubber solids, and scrap metals. The quantities and variations in the types of solid wastes generated are generally related to types of activities and production levels. Uranium contained in solid wastes is discussed in Table 3.

Environmental Data

Environmental data for ORGDP has been collected and analyzed since 1959. Because of variability in the data and natural conditions, such as weather, there often is not a good correlation between the release data of Tables 1, 2, and 3 and the environmental data measured offsite. Sampling ambient air for uranium concentrations dates back to 1960. Data was taken from locations at a two and five-mile radius from ORGDP (Map Number 1). This sampling program continued through 1965. A summary of this data is presented in Table 4. In 1966, an ambient air monitoring program, for Long-Lived Gross Alpha Activity (uranium), was initiated at two locations (Map Number 2) and continues to the present. This data has been presented in Table 5. All values reported are well below the applicable concentration guide with the exception of some values reported in 1960. A single period of increased activity occurred in November of 1960 and coincided with a pilot plant activity. Not included in this data are thirty-two samples taken in early November which coincided with an onsite pilot plant operation. These values showed 188×10^{-13} µCi/mL at two miles and 110×10^{-13} µCi/mL at five miles. Following completion of this activity, all values very rapidly returned to background.

Measurements of uranium concentrations in surface streams have been determined since 1959. Over the years, samples have been collected at six different locations; three on Poplar Creek and three on the Clinch River (Map Number 3). Poplar Creek has been designated for fish and aquatic life, and Clinch River for drinking water use. There are no current drinking water standards for uranium. Values presented in Table 6 are well within the applicable DOE concentration guide.

Data on the concentration of uranium in the sediment of Poplar Creek and Clinch River has been collected since 1976 and shown in Table 7 (Map Number 4). No trend can be established from this data. The concentrations fluctuate from year to year, but when viewed over the eight-year period, show very little change in uranium concentrations. The Interagency Oak Ridge Task Force is evaluating the significance of elevated pollutant limits in the Oak Ridge area creek sediments.

Measurements of uranium concentrations in groundwater are presented in Table 8 (Map Number 5). Groundwater measurements have been made for five years at twenty-one locations. Groundwater monitoring activities have been conducted on two facilities at ORGDP. These are the K-1407-C Holding Pond and the K-1070-D Classified Burial Ground. Uranium values are generally very low and very close to background levels. Values range from less than 0.067×10^{-8} μCi/mL to 0.738×10^{-8} μCi/mL.

Soil and vegetation data is presented in Tables 9, 10, and 11 (Map Number 2). Samples have been taken since 1974. A review of the data indicates that the years 1975-76 had relatively low soil concentrations compared to subsequent years. The meaning of this is not clear. For vegetation data, concentrations have varied very little over the duration of the sampling program. While the concentrations are slightly above background, they would not constitute a major source of radiation exposure.

In 1977, fish from both Poplar Creek and Clinch River were analyzed for uranium. Concentrations of uranium in fish from Poplar Creek ranged from less than 0.005 ppm to 0.061 ppm. Concentrations of uranium in fish from Clinch River ranged from less than 0.005 ppm to 0.072 ppm. In 1982, fish from Poplar Creek were again analyzed for uranium. Concentrations ranged from less than 0.003 ppm to 0.025 ppm. The uptake of uranium from the ingestion of fish is not considered a major pathway for public exposure to radioactivity.

Radiation Exposure Calculations and Estimated Human Health Impact

The total radiation exposure, of all residents within 50 miles of the K-25 plant, has been calculated based on total uranium airborne emissions recorded from 1946 through 1983. Table 12 evaluates the human health impacts from these releases. These data indicate a total of eight-hundred and fifty person-rems over that period. See Appendix A for further discussion. This compares to the expected total population dose of 4.9 million person-rems from natural sources of radiation in the same fifty

mile radius. These latter calculations take into account the increasing population since 1946 and an average annual background dose per person of 200 mrem. Potential health effects (fatal cancers) were estimated by multiplying the total population dose of 850 person-rems by 1.65×10^{-4} (0.000165) health effects per person-rem. The resulting estimate of 0.14 can be interpreted to mean that it is unlikely this health effect occurred as a result of uranium releases. A value of 1.0 mean would that approximately one fatal cancer, somewhere within a 50 mile radius of the plant, could occur as a result of uranium discharges.

Calculations of the dose for measured uranium discharges in 1984 to the maximum exposed members of the public indicate that less than 1 mrem of effective total body dose occurred. This can be compared to an EPA annual dose limit of 25 mrem. Dose estimates for the plant were made using the AIRDOS mathematical model. All major pathways of exposure from airborne releases (inhalation, ingestion, and direct radiation) were considered in the calculations. Appendix B provides an explanation of applicable environmental radiological standards.

Table 1
DOE-ORGDP
Airborne Uranium Emissions
1946 - 1983

YEAR	Total Uranium Radioactivity Released (Ci/yr)	Total Mass of Uranium Released (kg/yr)
1946	0.01	1
1947	<0.01	<1
1948	<0.01	5
1949	<0.01	45
1950	0.10	136
1951	0.02	146
1952	0.23	345
1953	1.60	1,307*
1954	0.26	68
1955	0.26	264
1956	0.81	225
1957	0.15	306
1958	1.80	2,711*
1959	1.10	531
1960	1.50	977
1961	3.10	773
1962	0.24	29
1963	3.10	1,005*
1964	0.01	7
1965	0.14	269
1966	<0.01	1**
1967	<0.01	2
1968	<0.01	<1
1969	<0.01	9
1970	<0.01	8
1971	0.02	21
1972	0.03	49
1973	0.13	144
1974	0.44	622
1975	0.27	371
1976	0.05	45
1977	0.03	17
1978	0.02	19
1979	0.04	25
1980	0.03	21
1981	0.01	5
1982	<0.01	2
1983	<0.01	2
TOTAL	15.60[1]	10,515[1]

[1]This total includes the actual stated value for any quantity which was reported as a less than (<) value.

Note: The isotopic content of the uranium released varies strongly from year to year (Uranium-235 content varies from 0.2 percent to 90+ percent). The variability of isotopic content and quantities released results in much year to year variation.

* A major portion of the quantities reported in 1953, 1958, and 1963 resulted from accidental releases due to valve and trap failures in the K-402-1, K-1131, and K-1420 feed and processing facilities.

** Declining production levels was a factor which reduced emissions in the 1966-70 time period.

Table 2
DOE-ORGDP
Liquid Effluent Uranium Releases
1946 - 1983

YEAR	Total Uranium Radioactivity Released (Ci/yr)	Total Mass of Uranium Released (kg/yr)
1946	<0.01	<1
1947	—	—
1948	0.03	4
1949	<0.01	3
1950	—	—
1951	0.05	80
1952	<0.01	4
1953	0.10	26
1954	0.23	84
1955	0.05	16
1956	0.24	90
1957	0.18	40
1958	<0.01	<1
1959	<0.01	5
1960	<0.01	<1
1961	0.02	2
1962	0.01	2
1963	5.10**	1,576*
1964	1.10	1,826*
1965	0.01	33
1966	<0.01	21
1967	<0.01	12
1968	0.26	330
1969	0.04	3,180*
1970	0.86	88
1971	0.44	76
1972	0.40	1,601
1973	0.44	570
1974	0.4	508
1975	1.70	564
1976	0.54	306
1977	0.42	2,201*
1978	0.63	688
1979	0.47	537
1980	0.09	803
1981	0.18	601
1982	0.09	114
1983	0.18	233
TOTAL	14.34[1]	16,227[1]

— Indicates data not available

[1]This total includes the actual stated value for any quantity which was reported as a less than (<) value.

Note: The isotopic content of the uranium released varies from year to year (Uranium-235 content varies from 0.2 percent to 90+ percent). The variability of isotopic content and quantities released results in much year to year variations.

* A major portion of the quantities reported in 1963, 1964, 1969, 1972, and 1977 resulted from discharges to a pond from the decontamination facility.

** Enriched material.

Table 3
DOE-ORGDP
Uranium Contained in Solid Waste Buried on Site

YEAR	Total Uranium Radioactivity Buried (Ci/yr)	Total Mass of Uranium Buried (10^3 kg/yr)
1958	1.20	1.79
1963	5.50	1.70
1964	1.10	1.99
1965	<0.01	<0.01
1966	0.99	1.93
1968	0.37	0.60
1969	1.80	4.78
1970	0.87	1.21
1971	0.08	0.13
1972	10.70	27.50*
1973	1.80	2.46
1974	0.55	0.71
1975	0.59	0.76
1976	0.95	1.34
1977	2.50	3.18
1978	0.85	1.09
1979	1.20	1.56
1980	1.20	1.86
1981	0.83	1.06
1982	0.43	0.55
1983	0.18	0.29
TOTAL	33.70	56,500 kgs

Note: The ratio between curies and mass differs from year to year due to varying isotopic enrichments.

* Contaminated scrap from previous years was buried.

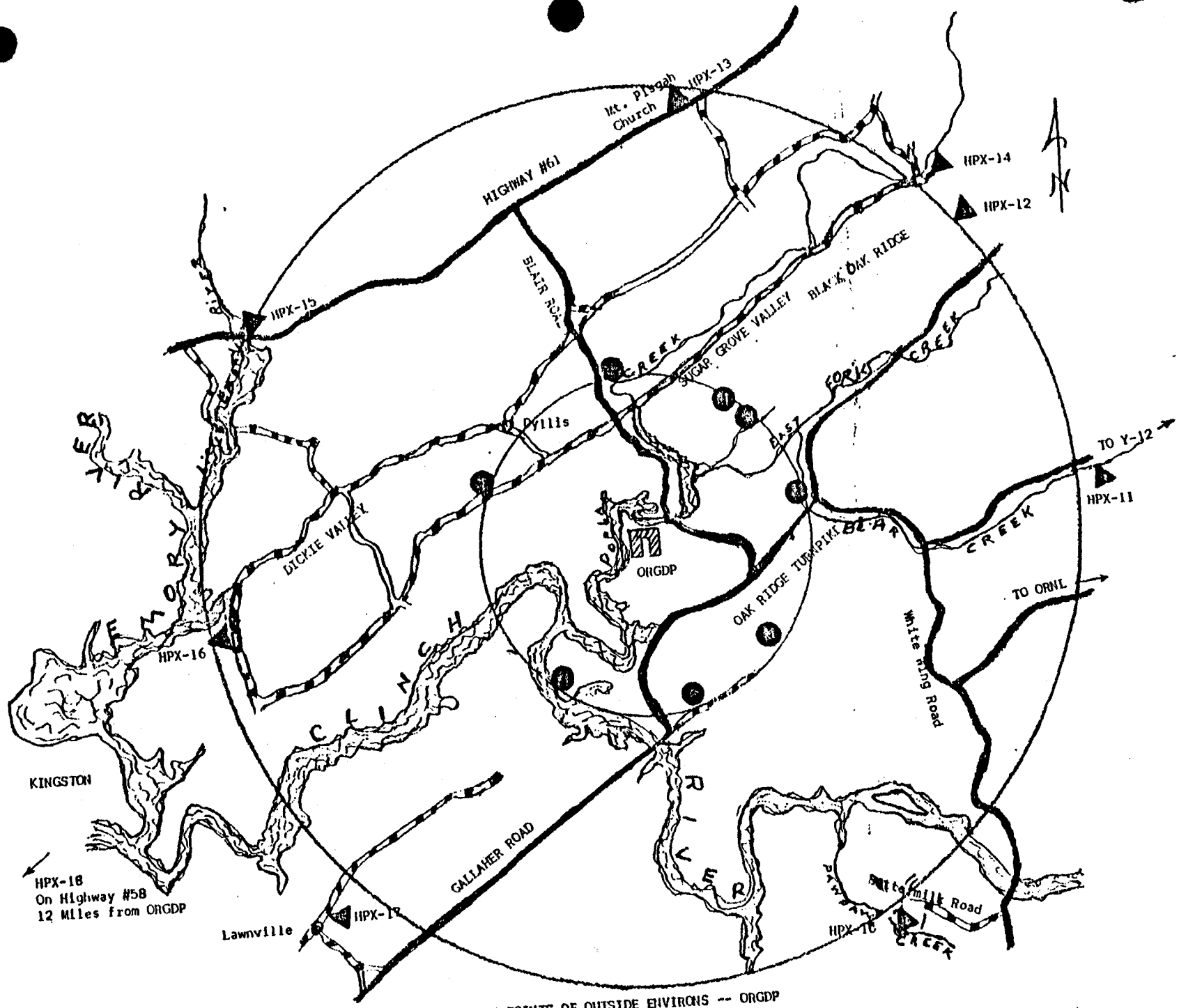
Table 4
ORGDP Annual Air Concentration
(1960 - 1965)
10^{-13} µCi/mL

Year	Distance From ORGDP	Average*** Concentration	Concentration Guide
1960*	2 miles	1.1	20
1960*	5 miles	3.1	20
1961	2 miles	0.4	20
1961**	5 miles	1.0	20
1962	5 miles	1.6	20
1963	5 miles	4.0	20
1964	5 miles	2.5	20
1965	5 miles	0.8	20

* Not included in this data are thirty-two samples taken in early November which coincided with an onsite pilot plant operation. These values showed 188 x 10^{-13} µCi/mL at two miles and 110 x 10^{-13} µCi/mL at five miles.

** After 1961 the two mile stations were not maintained.

*** The values in Table 4 are higher than the values in Table 5 because the data in Table 4 were collected without waiting for the background daughter products to decay. The air monitors used during this period automatically counted the air samples only 4.5 hours after collection. Sampling methods were changed in 1966 to correct this deficiency.



SAMPLING POINTS OF OUTSIDE ENVIRONS -- ORGDP

Air

▲ Sampling Location - 5 Miles from Plant

Sampling Location - 2 Miles from Plant

Table 5
Annual Air Concentration (1966-1983)
(Average Gross Alpha Activity - 10^{-15} μCi/mL)

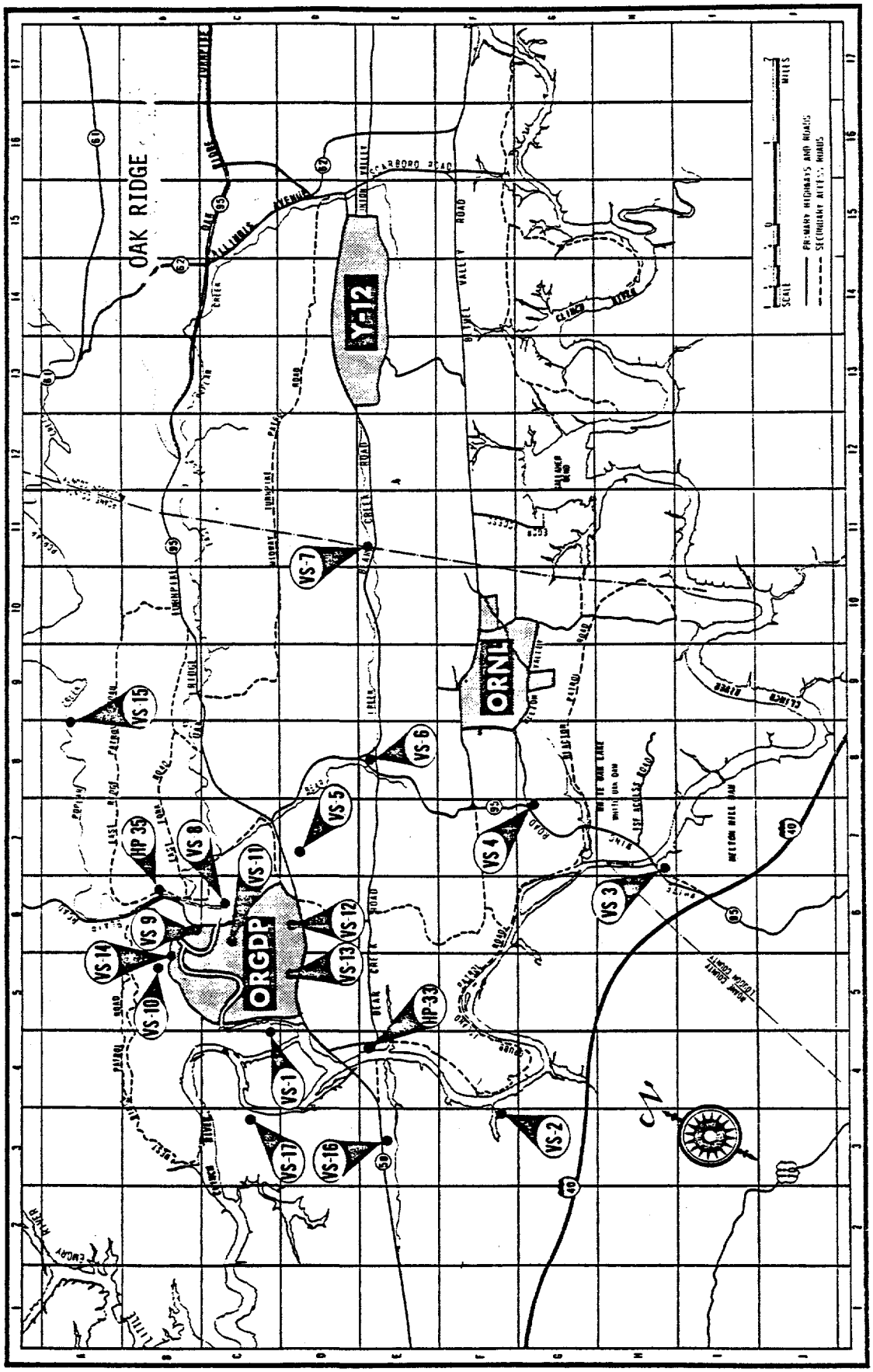
Year	Location HP - 33 Gallaher Gate	*Percentage of Concentration Guide (%)	Location HP-35 Blair Gate	*Percentage of Concentration Guide (%)
1966	5.0	.12	7.0	.17
1967	3.0	.07	5.0	.12
1968	1.5	.04	2.0	.05
1969	1.5	.04	2.0	.05
1970	1.0	.02	1.0	.02
1971	1.0	.02	1.0	.02
1972	2.0	.05	3.0	.07
1973	1.6	.04	2.3	.06
1974	1.5	.04	1.6	.04
1975	1.4	.03	1.6	.04
1976	1.7	.04	3.1	.08
1977	1.6	.04	1.3	.03
1978	1.1	.03	2.2	.05
1979	1.2	.03	1.5	.04
1980	1.1	**	1.5	**
1981	0.8	**	0.9	**
1982	1.1	**	1.0	**
1983	1.3	**	1.0	**

* The applicable concentration guide until 1980 was 4.0×10^{-12} μCi/mL.

** Beginning in 1980, a dose standard as opposed to the concentration standard was adopted. See discussion of 40 CFR 190 in Appendix B.

MAP NUMBER 2

DWG. NO. K/G-85-4261 (U)



AIR, VEGETATION, AND SOIL SAMPLING LOCATIONS

Table 6
Surface Water Concentration
10^{-14} Ci/mL

Year	*No. 1	*No. 2	*No. 3	*No. 4	*No. 5	*No. 6	Concentrati Guide
1959	6.2		0.6				2,000
1960	3.1		0.7	0.14	0.27		2,000
1961				0.16	0.25		2,000
1962				0.06	0.2		2,000
1963							2,000
1964				0.1	0.1		2,000
1965				<0.1	<0.1		2,000
1966					<0.1		2,000
1967					<0.1		2,000
1968					<0.2		2,000
1969					<0.1		2,000
1970					<0.1		2,000
1971		2.5	7.1		0.3		2,000
1972		1.0	0.4		0.2		2,000
1973		0.6	0.1	<0.2	0.2		3,000
1974		3.2	2.1	0.5	0.3		3,000
1975		1.6	1.0	0.3	0.4		3,000
1976		1.2	1.4	0.5	<0.6	<0.5	3,000
1977		1.0	0.6	0.3	0.2	0.3	3,000
1978		<0.3	<0.4	<0.1	<0.3	<0.3	3,000
1979		<0.4	0.5	<0.2	<0.3	<0.2	3,000
1980		<0.2	<0.4	<0.09	<0.2	<0.1	**
1981		0.5	0.6	<0.01	<0.1	<0.2	**
1982		<0.2	<0.3	<0.1	<0.1	<0.1	**
1983		<0.4	<0.4	<0.2	<0.2	<0.2	**

*1. Mouth of East Fork Poplar Creek

*2. Above K-25 Poplar Creek

*3. Mouth of Poplar Creek

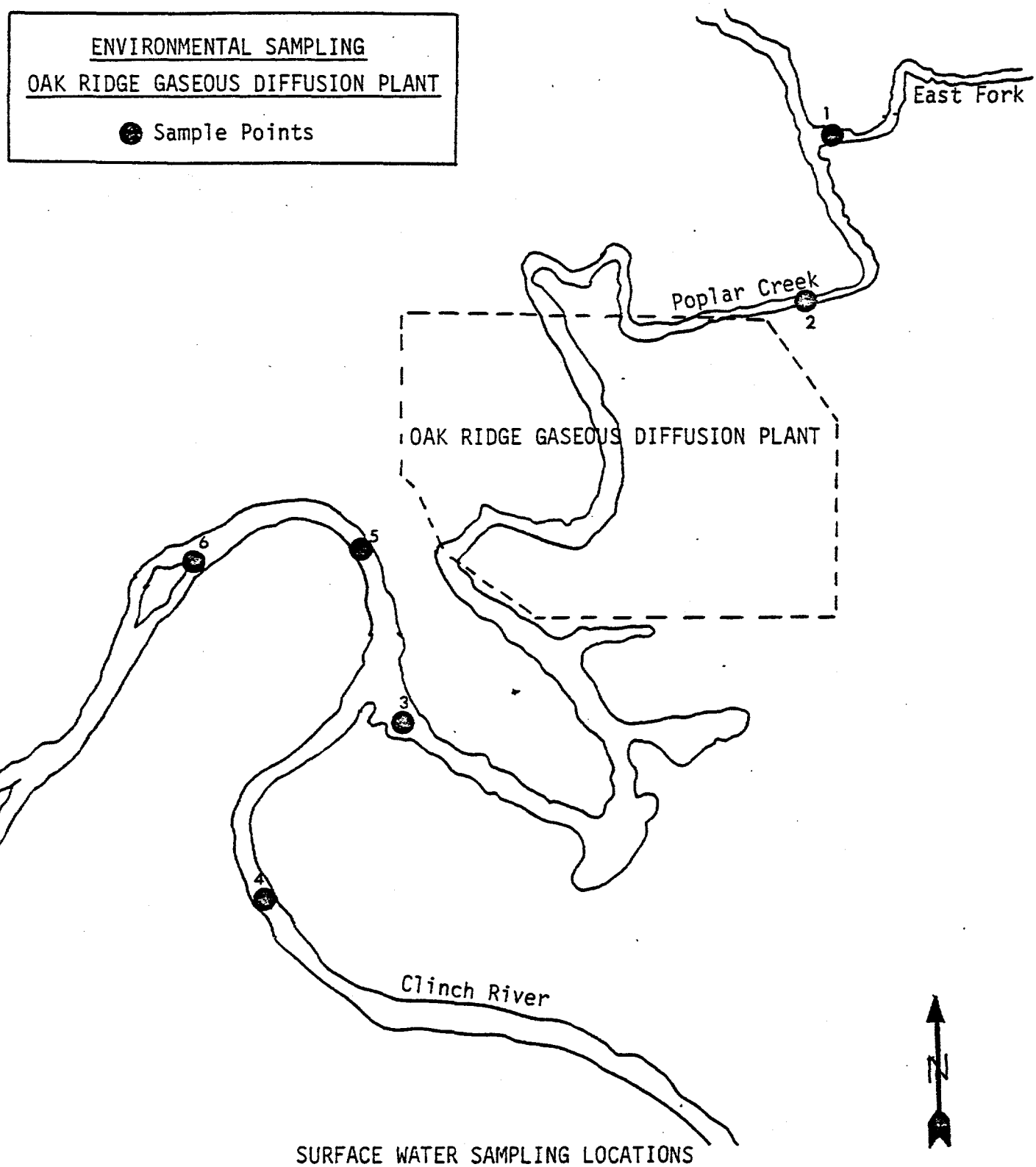
*4. Above K-25 Clinch River

*5. Below K-25 Clinch River

*6. Brashear Island Clinch River

** - Beginning in 1980, a dose standard as opposed to the concentration standard was adopted. See discussion of 40 CFR 190 in Appendix B.

Map Number 3



SURFACE WATER SAMPLING LOCATIONS

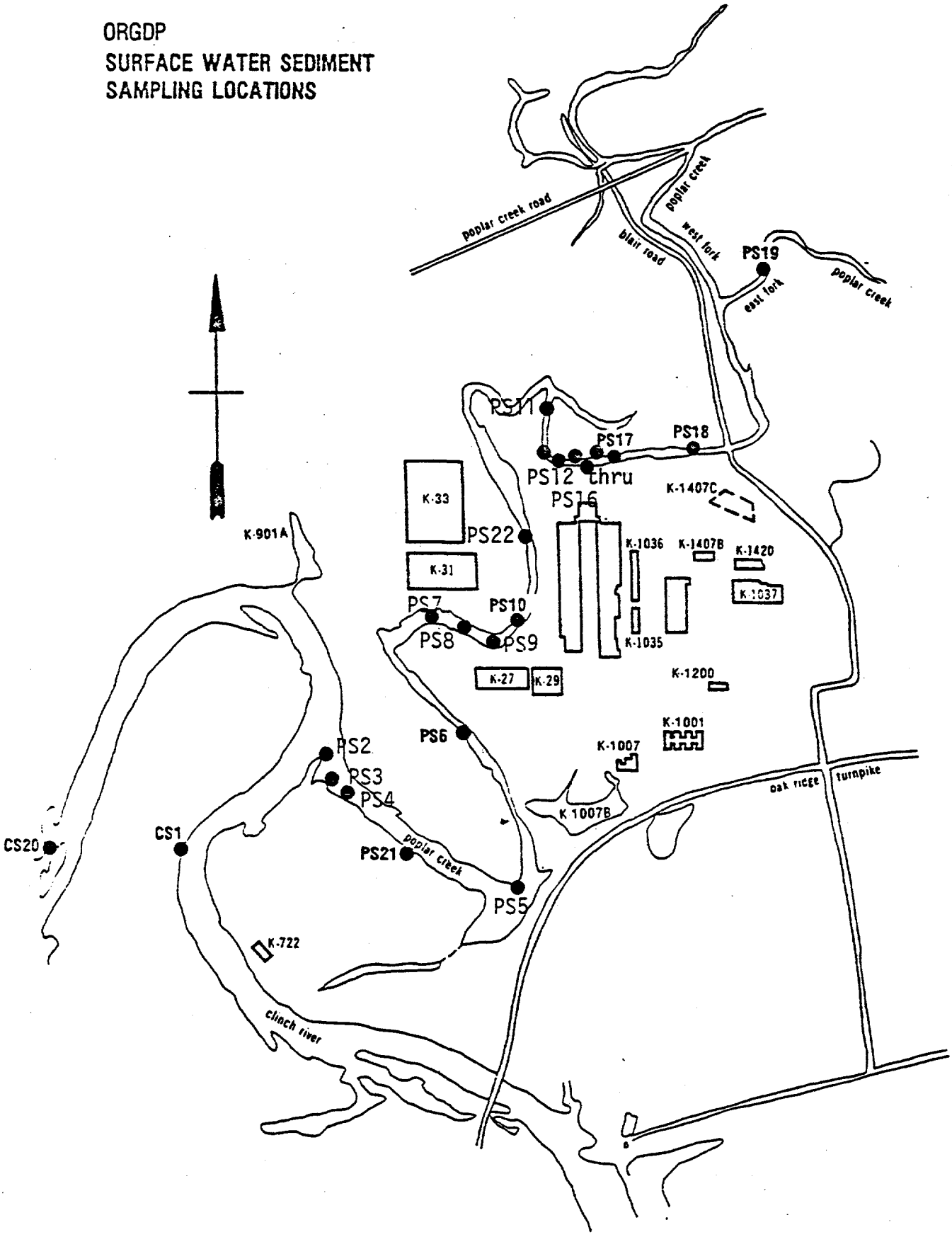
Table 7
Uranium in Stream Sediments
(μg/g)

	1976	1977	1978*	1979	1980	1981	1982*	1983
CS-1	0.4	2.1	16	2	1	1	1	4
PS-2	3.4	10.4	15	17	8	7		
PS-3	4.1	10.8						
PS-4	8.6	15.9						
PS-5	11.1	4.9	9	5	6	6		
PS-6	11.6	38.5	14	14	18	11	6	9
PS-7	59.5	4.5						
PS-8	6.1	5.3						
PS-9	17.8	22.6	4	6	4	3		
PS-10	18.2	4.9	21	4	17	18	10	9
PS-11	2.4	9.5						
PS-12	4.8	4.5	17	17	4	9		
PS-13	23.4	5.9						
PS-14	6.3	20.9						
PS-15	12.6	8.1	95	14	31	31		
PS-16	62.1	42.0						
PS-17	4.5	90.8	12	181	13	13	59	65
PS-18		12.1	6	6	4	6	13	9
PS-19		15.3	9	17	9	12	10	13
PS-21			13	7	7	1	8	13
PS-22			10	12	8	7		
CS-20		1.4	8	1	1	11	1	1

* In 1978 and again in 1982, the number of stream-sediment sampling locations was reduced.

Map Number 4

ORGDP
SURFACE WATER SEDIMENT
SAMPLING LOCATIONS



OAK RIDGE GASEOUS DIFFUSION PLANT SEDIMENT SAMPLING LOCATIONS

Table 8
Groundwater Uranium Concentration*
10^{-8} µCi/mL

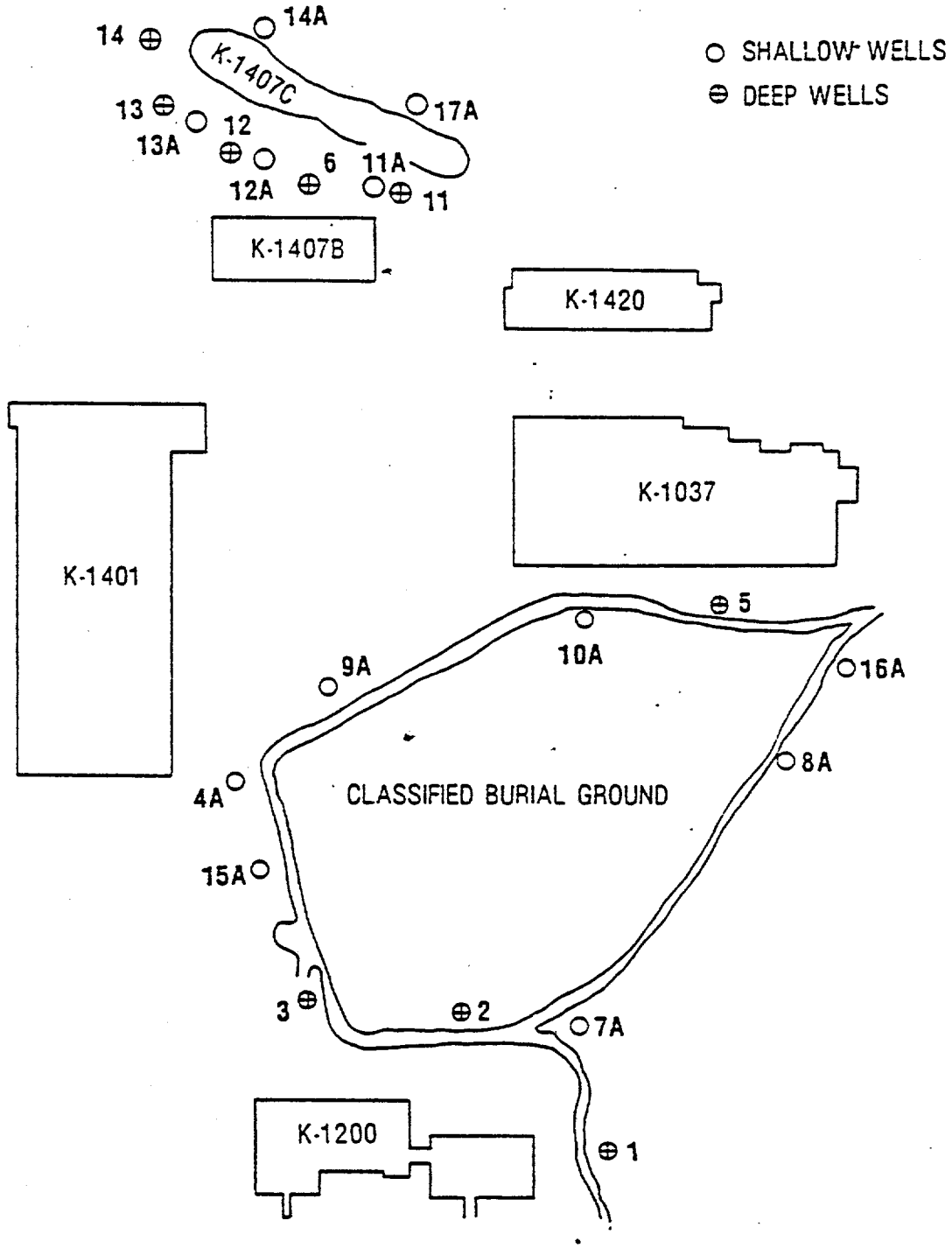
	1979	1980	1981	1982	1983
#1	<0.067	<0.067	<0.067	0.134	0.067
#2	<0.067	<0.067	0.134	0.067	0.201
#3	<0.067	<0.067	<0.067	<0.067	0.134
#4A				0.067	0.738
#5	<0.067	<0.067	<0.067	<0.067	0.201
#6	0.134	0.201	0.134	0.268	0.335
#7A				0.134	0.268
#8A				<0.067	0.536
#9A				0.201	0.536
#10A				0.201	0.402
#11				0.134	0.268
#11A				0.671	0.201
#12				<0.067	<0.067
#12A				0.469	<0.067
#13				0.067	<0.067
#13A				0.067	0.067
#14				0.201	<0.067
#14A				0.067	<0.067
#15A				<0.067	0.201
#16A				0.402	0.671
#17A				0.201	<0.067

* Assumed activity for natural uranium 1.49×10^{6} gm/Ci

Map Number 5

ORGDP

GROUNDWATER MONITORING WELLS



ORGDP GROUNDWATER MONITORING WELL LOCATIONS

Table 9

Uranium in Soil

(µg/g)

	1975	1976	1977	1978	1979	1980	1981	1982*	1983
VS-1	2.1	1.5	4.1	3.0	2.4	2.1	2.3	1.5	4.2
VS-2	4.8	1.5	1.0	1.7	1.6	3.0	3.4		
VS-3	1.1	1.1	2.0	3.1	2.6	2.2	3.2		
VS-4	0.4	0.8	1.1	1.8	3.1	1.9	3.3		
VS-5	1.1	0.6	2.4	2.7	2.2	2.5	2.2	2.9	4.7
VS-6	0.9	1.1	2.1	4.2	4.6	1.8	3.9		
VS-7	0.5	0.8	2.2	2.2	2.0	5.4	2.6		
VS-8	1.1	1.7	4.2	5.8	4.1	5.5	4.1	4.9	4.6
VS-9	0.8	0.4	1.6	2.7	2.6	4.5	2.4	1.8	2.4
VS-10	0.6	0.3	3.4	3.9	2.3	2.2	1.8	2.0	2.3
VS-11	1.4	0.9	2.9	4.5	4.9	2.5	5.3	4.6	6.0
VS-12	1.0	0.6	1.8	2.1	3.4	2.0	2.9		
VS-13	2.9	2.8	4.2	4.9	3.7	2.9	2.8	2.5	3.7
VS-14	1.2	1.9	2.1	2.4	3.2	1.5	2.3		
VS-15	1.5	1.0	3.7	3.5	4.0	3.2	5.4	3.2	3.8
VS-16	1.0	2.4	1.9	2.0	4.1	2.2	2.5	1.6	2.8
VS-17	2.9	1.0	5.8	6.5	3.3	3.2	1.6	2.2	1.6
Annual Average	1.5	1.2	2.7	3.3	3.2	2.8	3.1	2.7	3.6

* In 1982, the number of soil sampling locations was reduced.

Table 10

Uranium in Pine Needles

(µg/g)

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
VS-1	<0.1									
VS-2	<0.1	<0.1	<0.1	0.89	0.04	0.06	0.2	0.09		
VS-3	<0.1	<0.1	0.1	0.26	0.06	0.05	0.3	0.1		
VS-4	<0.1	<0.1	0.1	0.07	0.2	0.1	0.2	0.3		
VS-5	<0.1	0.2	0.4	0.21	0.2	0.2	0.5	0.1	0.1	0.32
VS-6	<0.1	<0.1	0.1	0.08	0.04	0.09	0.3	0.2		
VS-7	0.3	<0.1	0.1	0.11	0.09	0.1	0.2	0.1		
VS-8	0.6	0.3	0.2	0.47	0.2	0.3	0.4	0.6	0.2	0.24
VS-9	<0.1	0.3	0.2	1.00	0.2	0.09	0.2	0.1	0.05	0.10
VS-10	<0.1	2.4	0.1	0.45	0.1	0.1	0.1	0.9	0.4	0.16
VS-11			0.3	0.82	0.5	0.5	1.1	0.4	0.1	0.20
VS-12			0.2	0.24	0.2	0.2	0.4	0.3		
VS-13*										
VS-14			<0.1							
VS-15			<0.1	0.25						
VS-16			0.2	0.18				0.1	0.08	0.13
VS-17			0.1	0.19				0.07	0.09	0.05
Annual Average	<0.2	<0.4	<0.2	0.4	0.2	0.2	0.3	0.3	0.1	0.2

* No pine needles available at this site.

** The number of sampling locations were reduced.

Table 11
Uranium in Grass
(µg/g)

	1974	1975	1976	1977	1978	1979	1980	1981	1982*	1983
VS-1	0.1	0.3	0.5	0.20	0.2	0.1	0.6	0.3	0.2	0.21
VS-2	0.6	0.1	0.1	0.08	0.05	0.1	1.6	0.2		
VS-3	0.1	0.1	0.1	0.04	0.04	0.1	1.2	0.06		
VS-4	0.2	0.3	0.7	0.38	0.2	0.1	0.7	0.1		
VS-5	<0.1	0.1	0.2	0.07	0.3	0.1	0.7	0.4	0.3	0.20
VS-6	<0.1	0.3	0.2	0.07	0.6	0.08	0.6	0.2		
VS-7	<0.1	0.2	0.1	0.06	0.5	0.1	0.5	0.5		
VS-8	<0.1	0.4	0.3	0.29	1.0	0.2	0.6	0.2	0.2	0.08
VS-9	<0.1	0.3	0.1	1.22	0.4	0.2	0.7	0.2	0.1	0.06
VS-10	<0.1	<0.1	0.1	0.16	0.4	0.1	0.5	0.2	0.2	0.05
VS-11			0.4	0.53	1.2	0.7	1.7	0.5	0.4	0.08
VS-12			0.2	0.12	0.4	0.2	0.4	0.2		
VS-13			0.1	0.51	0.8	0.1	1.1	0.6	0.6	0.63
VS-14			0.3	0.27	0.3	0.04	0.5	0.02	<0.1	
VS-15			0.1	0.07	0.3	0.04	0.6	0.2	0.2	0.08
VS-16			0.1	0.04	0.5	0.1	1.2	0.2	0.1	0.12
VS-17			0.1	0.12	1.1	0.4	0.8	0.06	0.1	0.11
Annual Average	<0.2	<0.2	0.2	0.2	0.5	0.2	0.8	0.2	0.2	0.2

* In 1982, the number of sampling locations were reduced.

Table 12
Health Effects From ORGDP Releases

	Population within 50 miles	
Average annual dose	22.40	person-rem
Percent of background	0.02	
Accumulated dose (38 yrs)	850	person-rem
Health effects (fatal cancers)	0.14	

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APPENDIX A

MEANING OF THE RESULTS

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MEANING OF THE RESULTS

INTRODUCTION

The preceding report, one of a series dealing with historic uranium discharges from DOE facilities, evaluates the discharges and environmental concentrations of this element. It also estimates the size of the health effects (fatal cancers) as a result of these discharges.

Because of its brevity and numerical orientation the body of the report did not deal with more general points such as the meaning of the results, relative risk, uncertainties in the data, and similar questions—the subject of this appendix.

THE MEANING OF THE RESULTS

These documents on dealing with DOE uranium discharges have shown much data and discussed them at length. What do these numbers mean in terms of health effects? This is what many members of the public will be asking. Our clear responsibility is to answer these questions.

There are at least two ways to evaluate the numbers. First is to consider them by themselves, without reference to any other considerations. This might be called the "headline" approach in which the bare facts are presented without explanation. A second, perhaps more rational, approach is to relate a given health effect to others. This is sometimes called comparative risk analysis or putting risks into perspective.

By comparing the risks to health due to these DOE facilities to other risks encountered in daily life, we are in no way belittling the effects produced by these facilities. For the individual or individuals who suffer from these effects, the fact that they are comparatively small compared to other risks will probably not mean too much.

There are many compilations of comparative and relative risks. One often quoted is "A Catalog of Risks," by B. L. Cohen and I. Lee, Health Physics, Vol. 36, no. 6, p. 707 (1979). Other data is available in annual almanacs such as "Information Please." In the interests of brevity, only a few examples are quoted.

In interpreting the numbers, a specific benchmark can be chosen. The Anderson-Roane County area in Tennessee had a population within 50 miles of the three DOE facilities located there of about 800,000 in 1980. In prior years the population was lower. For simplicity, assume that from 1946, the year of the first recorded uranium emissions data for the Anderson-Roane County facilities, to the present the average population in this region was about 600,000. Then if about 40 years of exposure (from 1946 to 1985) are considered, the number of person-years is about 40 x 600,000, or 24 million.

We can now estimate the annual number of deaths that would occur in a population of about 600,000 over 40 years. The almanacs will be used for the more common sources of death; the paper by Cohen for the more obscure sources. Note that only mortality is considered here as opposed to non-fatal morbidity.

If the U.S. death rates in the late 1970's had prevailed over the entire period considered, there would have been about 80,000 deaths in the region from heart disease, 43,000 from all types of cancer, and 20,000 from stroke. There would have been about 5700 deaths from influenza and pneumonia, 3400 from cirrhosis of the liver, and 3600 from diabetes. Even an almost-conquered disease like tuberculosis would have produced about 300 deaths.

Note that these and subsequent deaths tabulated in this section refer to the total over the entire 40 year period, not per year. This is to make them comparable in time scale to the health effects estimated as being attributable to uranium releases.

There would have been, at the late 1970's rate, about 11,000 total accident deaths. Of this number, about 5400 would have been due to motor vehicle traffic. Approximately half, or 2700, would have been alcohol-related. There would have been about 860 vehicle-pedestrian deaths. About 140 accidental deaths would have been associated with water transportation, and about 670 due to drowning.

Of the 43,000 cancers, about 3800 would have been in the breast, 5700 in the colon and rectum, and 11,000 in the lung.

The mathematical model used to calculate population doses for DOE facilities implies that the major health effect will be lung cancer from breathing in radionuclides. The expected 40-year total of 11,000 lung cancers in the population area may be compared to the one (or less than one) estimated for uranium releases from these facilities.

In each of the facility reports, mention is made of the natural background radiation dose that is incurred regardless of the presence of DOE facilities. There would have been an estimated 200-390 deaths from background radiation over the 40-year period.

A variety of other sources of death have been tabulated. Translated to the Anderson-Roane County region, they imply 660 deaths directly or indirectly related to drugs, 310 bladder cancer deaths due to coffee, 140 occupational accidental deaths, about ten from severe storms and perhaps ten from major fires and other disasters.

In summary, potential cancers due to uranium releases are, by any description, very small compared to most other sources of mortality.

DOSE MODELING AND ITS LIMITATIONS

The data in the accompanying report can be divided into two broad categories: effluents or discharges and measured concentrations.

Neither set of information directly gives the effect on human health. To estimate these effects, some type of mathematical model must be used.

Any model of this type leads further away from the original data, in that assumptions are needed to make the model produce a final result. Needed are data and assumptions about meteorology, population distributions, how radioactive material gets into the body and what it does once it gets there, and a host of other information.

The problem is not unique to calculations dealing with public radiation dose. To estimate air pollution and its effects, the Environmental Protection Agency and other groups use complex models. Oceanographers employ similarly complicated models to project ocean and weather conditions. In general, determining the overall effect of substances moving through air, water, and land will require some type of modeling.

All of the DOE facilities evaluated have monitoring stations. However, they do not have enough stations to precisely state the air concentrations at every point within a 50-mile radius of these facilities. It might take thousands of these stations. Therefore, a model has to estimate concentrations in places where there are no stations. A problem arises when the modeling estimate differs from the measured concentration. As noted below in the discussion of the specific model used, there is often a difference of a factor of two or more between measured and modeled levels.

There is frequently even less correlation between the size of effluent releases and concentration measurements. The rise and fall of the yearly quantities of effluents often do not coincide with the rise and fall of the measurements which are supposed to reflect those effluents. There are many possible reasons for this lack of correlation - weather patterns, possible inappropriate placement of the stations with respect to where the effluents are discharged, and so on. As well, measurements are in many cases so close to background concentrations that they are affected by only the largest variations in effluent discharges.

One area where modeling is especially useful is in estimating the dose to the maximally exposed person. Using the effluent data in combination with the concentration measurements alone will not identify the location of the hypothetical person or what dose he or she receives. A mathematical model can do this more inexpensively than other methods.

In summary, there are many fundamental limitations to any mathematical dose model. Yet there are other limitations, possibly as fundamental, in interpreting some of the concentration and effluent measurements made on uranium. As a result, none of the data or models used here can be (or are) considered perfect.

AIRDOS-EPA MATHEMATICAL MODEL OF RADIATION DOSE

Noted in the previous section, a mathematical model is needed to estimate the total radiation dose incurred by the population (population dose) surrounding a DOE uranium-discharging facility, as well as to estimate the maximum dose received by any member of the public.

The AIRDOS-EPA model (to be referred to as AIRDOS) is one of a number of computer codes used to estimate radiation dose to the public from airborne emissions. Liquid effluents and releases from the burial of solid wastes have to be evaluated by other models.

The advantages of the AIRDOS model are two-fold. First, it agrees reasonably well - usually within a factor of two or three - with measurements of radioactivity concentrations in air. Second, the Environmental Protection Agency has used it in setting some of their air quality regulations.

The AIRDOS model calculates annual doses to the public. It does this by estimating radionuclide concentration in air; the rate of deposition of these radionuclides to the ground; their concentration on the ground; concentration in streams into which radionuclides have fallen; human intake of radionuclides by breathing; concentration in meat, milk and fresh vegetables grown in areas where the radionuclides have fallen; and doses to humans from eating this food and breathing this air.

The dispersion of radionuclides into the air from their original source is described mathematically by using a so-called Gaussian plume model. This type of model is common. It is mandated for many regulatory applications by the U.S.E.P.A, and is found in various forms in a variety of "approved" dispersion models. The governing dispersion parameters used in this model have been studied extensively.

AIRDOS has been used in a validation study around the Savannah River Plant at Aiken, South Carolina. Results indicate that the annual predicted ground-level air concentration exceeded the observed value for each of the 13 stations examined. The average factor of overprediction was about two. This suggests that the likelihood of AIRDOS underpredicting doses is probably small. Potential underprediction, or lack of conservatism, is usually avoided by risk analysts whenever possible.

The computer code AIRDOS is available to the public through the Radiation Shielding Information Center at Oak Ridge National Laboratory. Its title is R. E. Moore et al., "AIRDOS-EPA: A Computerized Methodology for Estimating Environmental Concentrations and Dose to Man from Airborne Releases of Radionuclides," report ORNL-5532, June 1979.

Some of the major assumptions, both numerical and otherwise, used in the AIRDOS model are as follows:

(1) Population. The population within 50 miles of the facility was used to calculate total dose. The 1980 census showed about 800,000 people within this radius for the three major DOE facilities in Anderson and Roane Counties. The 50-mile radius is commonly used in radiological dose assessment calculations. Almost all uranium will have fallen to the ground by that distance.

The uranium discharges in these reports are historic in nature, going back in at least one instance to 1946. It clearly is inappropriate to use present population in evaluating releases of decades ago. Estimates of the population around the facilities were based on censuses going back to 1940, with appropriate interpolation. Because population data on areas smaller than counties is difficult to obtain prior to 1970, the distribution in direction about the facilities in the 1980 census was assumed to prevail in earlier years.

(2) Meteorology. The direction and speed of the wind clearly will affect where and when the radionuclides fall. To avoid the complication of daily or weekly wind data, an annual compilation for the year 1984 was used for Y-12 and ORGDP. The Paducah installation used the year 1981. It is then assumed that this year is representative of previous and subsequent years.

(3) Shielding. Most people spend 80-90% or more of their lives indoors. This will tend to reduce the intake of uranium radionuclides due to breathing outdoor air, although their dose reduction may be reversed by breathing indoor-generated radon which has nothing to do with DOE facilities. The AIRDOS model assumes that the entire population lives outdoors continually, thus maximizing potential uranium intake. This is another example of conservatism, or the likely overestimation of dose.

(4) Food Production. There are few people left who produce all their meat and vegetables. The AIRDOS model assumes that 30% of food eaten in this region originates there, and the rest is imported from outside.

(5) Particle Size. The size of the radionuclide particles, or the dust particles to which they are attached, is of significance in estimating radiation dose. In general, the smaller the particles, the more they stay in the lung, and the greater the dose to the lung. Larger particles are removed in the nasal region. Since breathing usually is the largest source of dose calculated by this model for uranium, the particle size assumption is crucial to the result. In the calculations, a representative radius of one micron was assumed. This is one millionth of a meter, or about one-hundredth the thickness of this page.

(6) Solubility. The degree of solubility of the radionuclides affects the behavior of radionuclides in the body. The faster they dissolve in water, the faster they move away from the lungs to other parts of the

body. The dose to other organs then depends on the solubility. For ORGDP, it was estimated that 90% of the particles were very soluble by the time they entered the body, and 10% of medium solubility. For the Y-12 Plant, it was estimated that equal numbers of particles fall in the high, medium and low solubility classes. For Paducah Gaseous Diffusion Plant, values were about 70% very soluble; 25% medium solubility and 5% low solubility. For RMI, it is estimated that all particles had low solubility. These estimates are based on the chemical nature of the radionuclides emitted from each plant.

(7) Committed Dose. The dose to organs of the body depends on the length of time the radionuclides remain in the organ. For some radionuclides, natural elimination removes them within hours or days; for others, the radionuclides may remain for many years, irradiating the organ in question over this time. In these calculations, a cut-off period of 70 years was assumed as the longest period considered.

(8) Non-airborne Releases. The AIRDOS model considers only airborne releases. Yet the attached report shows data on liquid effluents and concentrations. Should they be included in the dose calculations?

The publication entitled "Environmental Assessment of the Oak Ridge Gaseous Diffusion Plant Site," report DOE/EA-0106, 1979, states that the waterborne doses from DOE facilities are less than one percent of the doses due to air releases. A more recent calculation (memorandum from T. W. Oakes, Oak Ridge National Laboratory, to W. F. Furth, dated May 20, 1985) estimates that, on the basis of measured effluents into nearby creeks and rivers, the ratio of waterborne dose to airborne dose from the Y-12 Plant and Oak Ridge Gaseous Diffusion Plant was 1% - 2%. Even these small ratios are probably higher than reality, since it was assumed that no uranium is removed from the water by a variety of processes, such as water treatment plants before it gets to the consumer. Some undoubtedly is. If these studies are any indication of the relative impact of the ratio of water- borne to airborne uranium effects, then it is reasonable not to include waterborne radioactive doses, at least to a first approximation.

About the same point can be made about burial of solid wastes. In this series of reports on DOE facilities, the largest source of uranium radioactivity, both in terms of weight and curies of activity, is in the solid wastes. The dose produced from these wastes will depend on how much uranium moves from these wastes into water which is subsequently used by the public. Based on measurements, in almost all cases the amount is close to zero. Preliminary calculations done for other locations have confirmed that the doses produced from uranium migration from solid wastes, at their present measured levels, will be extremely small in comparison to airborne-related doses.

(9) Natural Background. The size of the dose from natural radiation background, present regardless of the existence of DOE facilities, does not enter into AIRDOS calculations. However, since the population dose computed by AIRDOS can be compared to that of the background dose, a few words about the assumptions are in order.

Background radiation varies somewhat with location. The farther the population is above sea level, the higher the dose from cosmic rays from outer space. The more uranium and thorium in earth or rocks, the higher the background. For purposes of this study, an average background of 200 millirem per year (effective total body dose) was assumed, made up of (a) about 30 millirem from cosmic rays, (b) 30 from potassium in the body, (c) 80 from radon, and 60 from other sources. This data is shown in United Nations Scientific Committee on the Effects of Atomic Radiation, "Ionizing Radiation: Sources and Effects," New York, 1982. A population of one million would then receive a total dose of 1,000,000 x 0.200 = 200,000 rem annually.

CAN THOSE WHO WILL CONTACT CANCER BE IDENTIFIED?

A key assumption in this analysis is that the deaths, cancers or other health effects are statistical in nature. That is, a particular person or persons who may contact cancer cannot be identified as a result of these uranium emissions. All that can be stated is that there may be X deaths, where X is the number or numbers in the main body of this report.

In this sense, the problem is the same as that facing those who have estimated the risk associated with smoking cigarettes. Yet in general, those who will fall victim to cigarette-induced lung cancer, heart disease, or other ailments cannot be named. In some extreme cases, when for example someone has been smoking four packs a day for 40 years and contracts lung cancer, cigarettes are, with virtual certainty, the cause. But there are other instances where an extremely heavy cigarette smoker does not contract lung cancer. As a result, there is no list of names of these who have been felled by cigarettes.

Because the health effects due to uranium inhalation or ingestion are not peculiar to that element, the new cancer cases which are due to this source cannot be identified. If cancer were both rare and attributable mostly to uranium, it could be done. At present, it cannot.

PARTIAL DEATHS

In the reports which this appendix accompanies, the final results in terms of health effects are expressed as partial or fractional fatal cancers. The number of health effects due to uranium releases may be shown as 0.7 or 0.9, for example. This fractional value comes about because of the nature of the mathematical model.

Obviously, there is no such thing as a partial death. In terms of this report, the meaning of these numbers can be visualized as follows: suppose that the uranium releases producing 0.1 death for a given site

had been duplicated in say ten sites, each with exactly the same geography, meteorology, and so on. Within these ten sites, there would have been a strong chance that almost all would have shown no extra cancer due to the uranium releases, a slight chance that one or two sites would have shown one extra cancer, and an almost vanishing chance that one site would have shown two or more. In the language of the mathematician, the fractional values represent the average of a Poisson distribution. As an example, consider tossing a die. On average, six spots should come up one time in six, but it may come up on a specific roll.

UNCERTAINTIES IN THE RESULTS

Some of the numbers in the accompanying reports are shown to three or more significant figures. This should not obscure the fact that there is considerable uncertainty in the results and conclusions. In most instances, if not all, these uncertainties are on the down side. That is, the estimates of health effects, such as fatal cancers, are probably overestimated rather than underestimated.

A thorough discussion of all the potential uncertainties would take up considerable room and require much technical detail. For brevity, just a few major sources of uncertainty are noted:

(1) The single number chosen for converting person-rems into fatal cancers (0.000165 deaths per person-rem, taken from "Effects on Populations of Exposures to Low Levels of Ionizing Radiation," National Academy Press, Washington, 1980) may give the illusion of precision. Radiation scientists serving on the committee which drafted the aforementioned report and the International Commission on Radiological Protection usually believe that this value forms an upper limit. The lower limit is unspecified, although some scientists feel it may be as low as zero. While the band of uncertainty cannot be defined mathematically as yet, the fact that it exists makes the overall results less than precise. From the viewpoint of public policy, the number of cancer deaths estimated in the main body of this report is then probably an upper limit.

(2) The entire mathematical modeling process is itself subject to much uncertainty. The physical spread of radionuclides through the air, water and into bodies and specific organs is a complicated process. Some of the specific areas of uncertainty are outlined in the section on the AIRDOS model, which in these respects is similar to other models. The uncertainties include population questions, shielding of humans from radiation, the degree of radiation in food, how body organs react to radiation, the solubility of radionuclides in the body, and others. It is nearly impossible to estimate the overall degree of uncertainty produced as a result of these individual uncertainties. The scientists consulted on this question feel that because of the stringent (or conservative) assumptions used in the model, it will almost certainly yield an overestimate of the population dose.

(3) Much of the data on emissions into air, water and land are themselves uncertain. In the past, the present level of measurement and analysis was sometimes not achieved. This in turn led to estimates, rather than measurements, being made occasionally.

While past measurements are not always up to today's standards, we cannot make the measurements now that (by present practices) would have been wise to have made 39 years ago. Neither can we predict what the requirements 39 years in the future may be. Unfulfillable desires, or annoying uncertainties, were-are-and-will be with us.

(4) Similar statements about uncertainty can be made about the environmental, as contrasted to the effluent, measurements. Over the years, measurement techniques have improved dramatically. These improvements have made earlier measurements relatively uncertain in retrospect. Since the samples are no longer around, there is no way the measurements can be redone using more precise and accurate techniques.

(5) There are three isotopes of uranium, with atomic weights of 234, 235 and 238, which can be emitted from DOE installations. The dose incurred by the public will depend largely on their proportion. In some cases, especially in air emissions, these proportions are or were not known precisely.

(6) The AIRDOS model considers almost exclusively the effects of airborne radioactive emissions. The calculations do not include doses from radioactivity in surface or groundwater or which has leached from solid wastes buried in the ground. As noted above, these pathways contribute only little to total population dose. This source of uncertainty is likely smaller than the other sources in this appendix.

(7) The reports deal only with uranium discharges. It is possible that other radioactive elements may also produce significant population dose, and work is underway to investigate this possibility.

(8) There is a time delay associated with any cancers induced from the calculated radiation dose. This uncertainty in terms of time is not of the same nature as the others in this section, which deal with quantity. Yet it produces uncertainty in the conclusions to be drawn. The implication may have been given in the calculations that any health effects occur shortly after the radionuclides enter the body of the person who will eventually die. This is not the case. While the time delay in the effect depends on the type of cancer induced, specialists have estimated a delay of between 5 and 30 years between the time the dose is received and when the fatal cancer appears. A fatal cancer produced as a result of a dose in 1946, by this estimation, may have shown up as early as 1951 or as late as 1976. Similarly, a dose of today may show up in cancer mortality tables as soon as 1990 or as late as 2015. The type of fatal cancer that will be produced, or when it will occur, is not known. Because a natural way of thinking is to assume that effects follow shortly after cause, the question of time delays produces uncertainty in linking the two.

In summary, these are some of the major and minor sources of uncertainties in both the data and the calculations based on them. Some, like those associated with modeling and the ratio of dose to health effects are probably over-arching. Others, like changes in instrumentation and measurement over the years, probably are smaller areas of uncertainty. While it would be desirable to be able to say, as the statisticians do, that the results have a plus-or-minus of so much attached to them, it cannot be done. The uncertainties are of such a disparate nature that at present they cannot be combined mathematically.

VARIATION OF CANCER STATISTICS

The number of cancer deaths vary strongly from year to year and place to place. The health effects of DOE facilities due to uranium discharges are probably so small as to be almost undetectable given this natural variation in cancer rates.

Only a few selected tables and maps are shown. More data is available in W. B. Riggan et al., "U.S. Cancer Mortality Rates and Trends, 1950-79," Vols. 1-3, U.S. Government Printing Office, Washington, 1983, report EPA-600/1-83-015a.

Table 1 shows the variation in cancer mortality among both white and non-white males for counties around Anderson and Roane County, Tennessee (the site of the Y-12 Plant and the Oak Ridge Gaseous Diffusion Plant), for the years 1960-69 and 1970-79. Note that this is the total mortality, including dozens of specific types of cancer. This is not the incidence of cancer, which would include both fatal and non-fatal cases. It is likely that about the same conclusions would be drawn for data on cancer incidence among the same two groups.

Table 2 shows the variation in cancer mortality around the Paducah Gaseous Diffusion Plant for the years 1960-69 and 1970-79. Again we see considerable variation from decade to decade for most counties. A good part of the increases shown in many counties can be attributed to the population increase over the years. The cancer rates per 100,000 have remained more constant.

Statistical tests can be performed to estimate how variable these numbers are with respect to the estimated fatal cancers due to the DOE facilities. However, a mere scanning of the numbers shows that trying to detect one or fewer deaths per year due to these facilities would be futile, given the apparently natural variation in cancer mortality. The number of deaths often change substantially from one decade to the next. The variation would be even greater if particular years were compared to each other rather than decades.

The mathematical model cannot be used to predict, because of the low radiation dose calculated, which county or counties would suffer the one or fewer cancer deaths. It is then close to impossible, on the basis of Tables 1 and 2, to detect mathematically an increase in cancer deaths of the order of one or fewer, and to identify in which county or counties this increase occurred.

It may be contended that the above conclusion is drawn only because the total number of cancer deaths was considered. If the cancer or cancers produced by uranium discharges were concentrated in one or more body organs which otherwise had a low incidence of cancer mortality, detection of changes in rates due to DOE facilities would be easier, in principle. For example, lip cancers produced about one in 915 U.S. cancer deaths from 1950 to 1969 (T. J. Mason et al., "Atlas of Cancer Mortality for U.S. Department of Health, Education and Welfare," Publication NIH-75-780). If cancers due to DOE facilities were concentrated on a specific organ like this which constitutes a small part of total cancer mortality, it would be possible to detect more easily the statistical effect of these facilities.

On the basis of present knowledge, this is highly unlikely. The AIRDOS-EPA mathematical model predicts that most cancers due to airborne releases of radioactivity will occur in the lung. The cancer atlas referred to immediately above notes that about 14 percent, or one in seven, of all cancer deaths from 1950-1969 occurred in the trachea, bronchus and lung.

Tables 3 and 4 show data similar to that of Tables 1 and 2, except that only lung cancer deaths are considered. The total number of deaths is substantially decreased from those of Tables 1 and 2, because lung (and related) cancer deaths are only one segment of total cancer deaths. However, the same difficulty in identifying cancer deaths of the order of one recurs. There is so much natural variation in the numbers that we cannot state with any degree of certainty how many excess lung cancer deaths have occurred, or where they occurred. For example, Sevier County lung cancer deaths for white males rose by 63 during the course of one decade. Those for Hickman County, Kentucky, rose by only one. It should be noted that lung cancer deaths throughout the entire country went up substantially during this period. Tables 3 and 4 reflect this national increase. Data for each of the cancer sites listed in the cancer atlases could be presented, but this is not done for purposes of brevity. Subdividing the total cancer death rate by sites in the body where they occur will still not allow a definitive conclusion that these rates have changed as a result of DOE uranium discharges.

Finally, it might be contended that the overall cancer rates, as opposed to total deaths, may be higher than the national average due to uranium emissions. This is not the case, as shown in the four parts of Figure 1. These maps show that the ratio of total county cancer rates to the U.S. or state average varies considerably, and with a good degree of randomness geographically. The natural variability in county cancer mortality rates arises due to a host of environmental and human factors. The

information in Figure 1 suggests that most of these rates are not substantially above national or state averages.

Table 1. Total Cancers Around Anderson-Roane County, Tennessee

	White Males		Non-White Males		Population (Thousands)	
Counties	1960-69	1970-79	1960-69	1970-79	1960	1970
Anderson	332	523	18	29	60	60
Blount	344	560	26	37	58	64
Campbell	247	347	6	2	28	26
Claiborne	169	219	3	3	19	19
Jefferson	152	200	11	8	21	25
Knox	1677	2430	228	296	251	276
Loudon	173	235	9	7	24	24
Morgan	91	133	0	0	14	14
Roane	233	355	14	18	39	39
Scott	91	149	2	0	15	15
Sevier	168	298	1	2	24	28
Union	51	64	0	0	8.5	9.1

Table 2. Total Cancers Around Paducah Gaseous Diffusion Plant, Kentucky

	White Males		Non-White Males		Population (Thousands)	
Counties	1960-69	1970-79	1960-69	1970-79	1960	1970
Ballard	76	127	5	3	8.3	8.3
Caldwell	114	153	11	14	13	13
Calloway	166	243	9	12	21	28
Carlisle	68	85	1	2	5.6	5.4
Crittenden	69	123	2	5	8.6	8.5
Fulton	115	101	16	15	11	10
Graves	256	348	16	21	30	31
Hickman	68	79	3	8	6.7	6.3
Livingston	88	82	1	0	7.0	7.6
Marshall	143	242	0	0	17	20
McCracken	466	567	55	91	57	58
Trigg	72	90	10	11	8.9	8.6
Weakley, TN	224	300	19	24	24	29
Alexander, IL	123	133	65	57	16	12
Hardin, IL	62	76	0	1	5.9	4.9
Johnson, IL	69	112	1	1	6.9	7.6
Massac, IL	123	169	18	16	14	14
Pope, IL	41	57	0	0	4.1	3.9
Pulaski, IL	81	97	33	40	10	8.7

Table 3. Lung, Trachea and Bronchus Cancer Deaths Around Anderson-Roane county, Tennessee

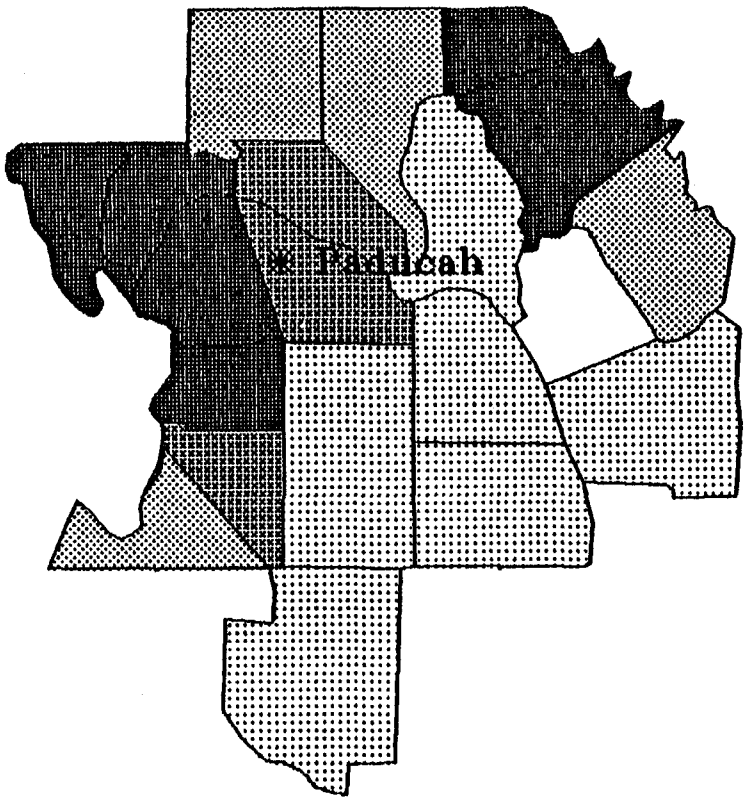
Counties	White Males		Non-White Males		Population (Thousands)	
	1960-69	1970-79	1960-69	1970-79	1960	1970
Anderson	112	215	6	9	60	60
Blount	104	204	5	12	58	64
Campbell	74	157	1	0	28	26
Claiborne	63	83	2	1	19	19
Jefferson	28	62	1	1	21	25
Knox	489	922	60	113	251	276
Loudon	50	86	3	0	24	24
Morgan	20	64	0	0	14	14
Roane	72	142	2	7	39	39
Scott	18	63	1	0	15	15
Sevier	41	104	1	0	24	28
Union	12	26	0	0	8.5	9.1

Table 4. Lung, Trachea and Bronchus Cancer Deaths Around Paducah Gaseous Diffusion Plant, Kentucky

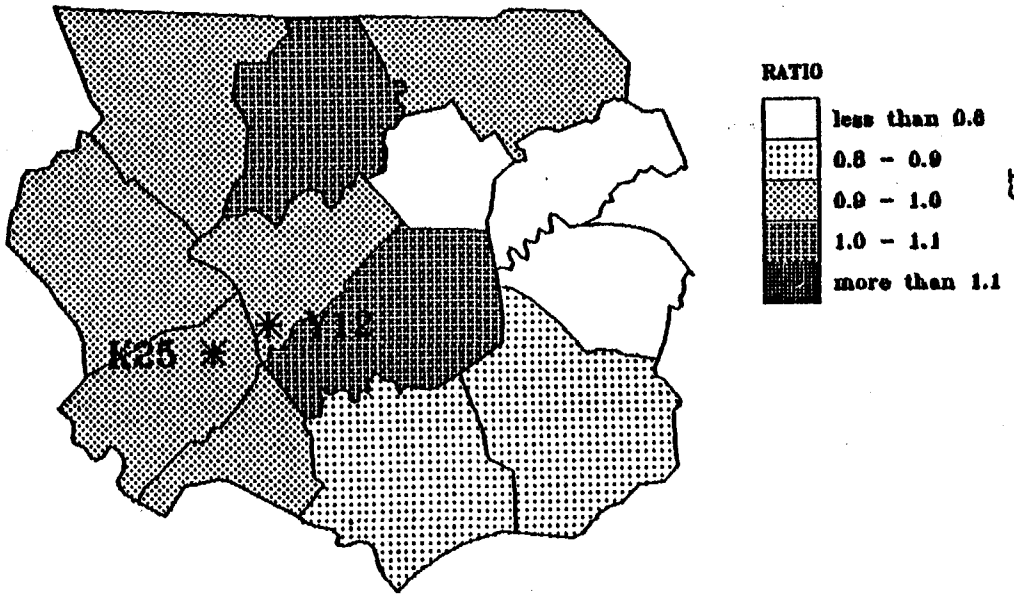
Counties	White Males		Non-White Males		Population (Thousands)	
	1960-69	1970-79	1960-69	1970-79	1960	1970
Ballard	16	52	1	1	8.3	8.3
Caldwell	27	57	2	4	13	13
Calloway	35	82	1	2	21	28
Carlisle	16	33	0	1	5.6	5.4
Crittenden	16	36	0	1	8.6	8.5
Fulton	38	40	4	6	11	10
Graves	59	119	3	9	30	31
Hickman	19	20	0	2	6.7	6.3
Livingston	20	27	0	0	7	7.6
Marshall	35	86	0	0	17	20
McCracken	129	219	13	26	57	58
Trigg	11	27	0	2	8.9	8.6
Weakley, TN	45	92	2	9	24	29
Alexander, IL	37	48	12	22	16	12
Hardin, IL	19	24	0	0	5.9	4.9
Johnson, IL	15	43	0	1	6.9	7.6
Massac, IL	43	57	2	3	14	14
Pope, IL	16	24	0	0	4.1	3.9
Pulaski, IL	27	34	3	12	10	8.7

Ratio of County Total Cancer Mortality Rate to National Average For White Males, 1970–1979

Paducah

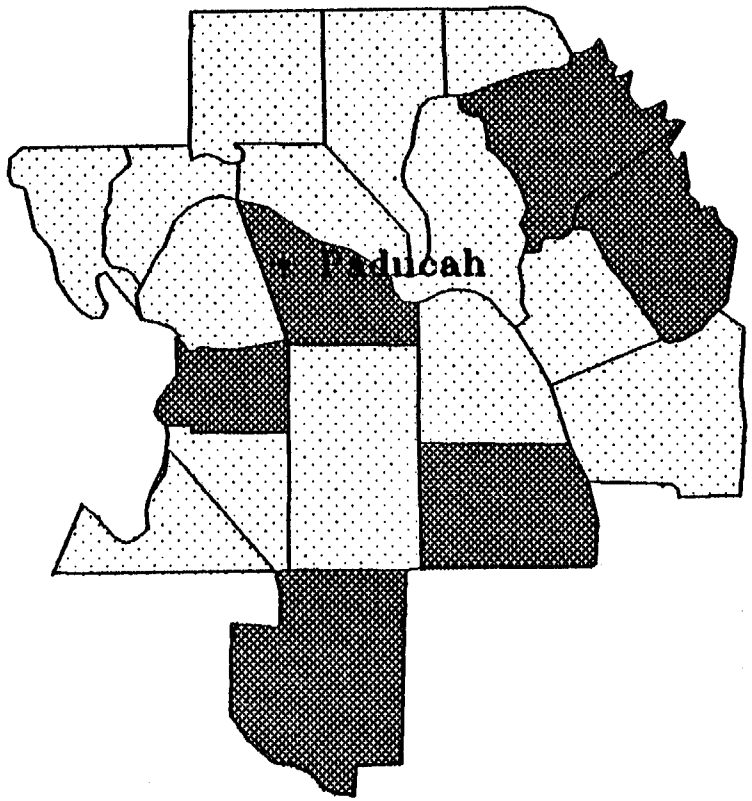


Oak Ridge



Ratio of County Total Cancer Mortality Rate to State Average For Non-White Males, 1970-1979

Paducah



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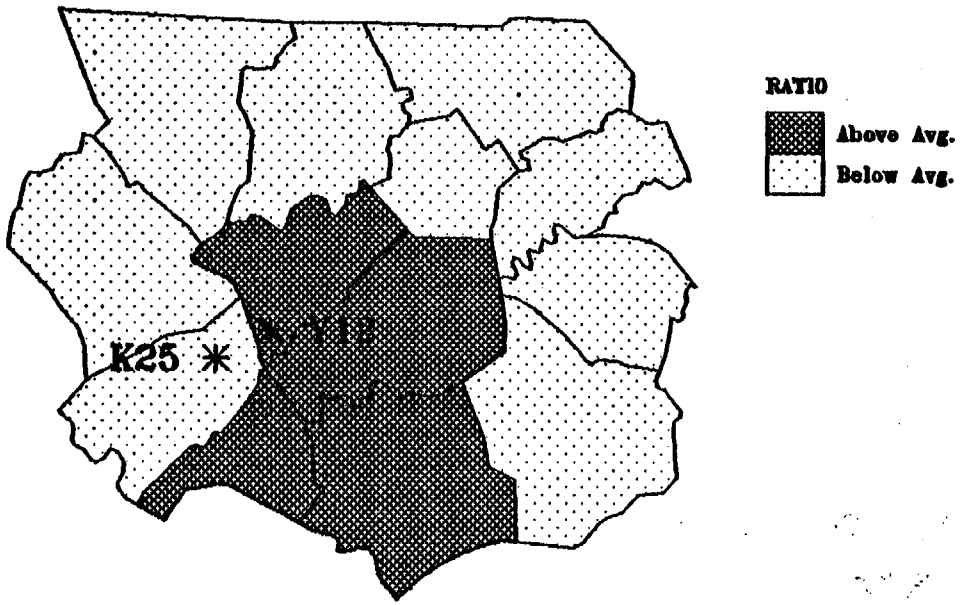

CONCLUSIONS

The precise conclusions of the preceding report will of course depend on the quantities involved. However, more general conclusions can be drawn on the basis of this appendix.

First, any fatal cancers as a result of uranium discharges will be small compared to other sources of cancer. In addition, these cancers will be very small compared to most other societal risks.

Second, there is no way that we can identify the victim or victims of these cancers, assuming that there is one or more. Cancer is too common. Lung cancer, probably the type produced by these uranium discharges, is also relatively common, especially among smokers.

Third, there is considerable variation from year to year and place to place of cancer death rates. This makes identifying the area where any effects are likely to happen almost impossible, given the low level of the health effects to be expected.

Fourth, there is considerable uncertainty in both the models used and some of the numbers fed into those models. From the viewpoint of public policy, these uncertainties will likely be in the direction of overestimating, rather than underestimating, these risks.

Emissions were higher in previous years, prior to the better control measures used today. Yet the cumulative risk produced by both present and past emissions has been small in comparison to those normally accepted by society.

APPENDIX B

RADIATION STANDARDS AND GUIDELINES

APPENDIX B

RADIATION STANDARDS AND GUIDELINES

This appendix presents several of the most important Federal radiation standards and guidelines, and describes the various ways in which they are applied. State standards are usually consistent with those of the Environmental Protection Agency and the Nuclear Regulatory Commission. States, however, are more directly concerned with the point of application of the standards; thus, their regulations in this regard will be discussed under the appropriate environmental media heading.

The NRC standards are not applicable to DOE operations, but are presented to illustrate their similarity with those of DOE and to point out, as well, how their application may differ.

I. Radiation Dose Standards

Public radiation dose standards have been issued by DOE, NRC, and EPA which are intended to limit exposures through all pathways, e.g., breathing air, water consumption, food consumption, and external radiation. The DOE and NRC standards are very similar, having the same basis. The EPA standard, however, is more stringent, since it was largely based upon limiting public exposures to levels which were considered to be "as low as reasonably achievable." Prior to establishing their standard, EPA performed a detailed study of the uranium fuel cycle industry for which the standard applies. This ALARA concept is a part of the DOE and NRC regulations, but it is not specifically quantified. (Several years ago NRC defined ALARA as $1000 per man-rem. In practice, much larger expenditures are being made to reduce public exposures.)

DOE:

DOE Order 5480.1 states the DOE radiation exposure standards for members of the public. "Exposures to members of the public shall be as low as reasonably achievable levels (and) within the standards prescribed below."

TABLE 1

Type of Exposure	Annual Dose Equivalent or Dose Commitment (mrem)*	
	Dose to Individuals at Points of Maximum Probable Exposure	Average Dose to a Suitable Sample of the Exposed Population**
Whole body, gonads, or bone marrow	500	170
Other organs	1500	500

*Dose commitment is the internal organ dose equivalent received over a 50-year period following intake of a radionuclide.

**An example of a "suitable sample of the exposed population" might be the residents of a nearby community.

New standards are expected to be promulgated by DOE in the near future consistent with the most recent recommendations of the National Council on Radiation Protection and Measurements. (See EPA air standards for further information on these recommendations.)

NRC:

The NRC radiation exposure standards for members of the public are contained in the Code of Federal Regulations 10 CFR 20.105. "There may be included in any application for a license or for amendment of a license proposed limits upon levels of radiation in unrestricted areas resulting from the applicant's possession or use of radioactive material and other sources of radiation. Such applications should include information as to anticipated average radiation levels and anticipated occupancy times for each unrestricted area involved. The Commission will approve the proposed limits if the applicant demonstrated that the proposed limits are not likely to cause any individual to receive a dose to the whole body in any period of one calendar year in excess of 0.5 rem."

EPA:

EPA has issued environmental standards (40 CFR 190) for the uranium fuel cycle that are applicable to those portions of uranium enrichment operations that directly support the production of electrical power for public use utilizing nuclear energy. These standards came into effect December 1, 1979.

Operations are to be conducted in such a manner as to provide reasonable assurance that the "annual dose equivalent does not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment and to radiation from these operations."

II. Radioactivity in Air Standards/Guidelines

DOE uses air concentration guides as guidelines only, whereas the corresponding NRC values are considered to be maximum permissible concentrations, or standards. A second difference is that NRC in most licensing actions applies their concentration limits to site boundaries rather than to the location of maximum offsite exposure.

EPA has not issued concentration guides or concentration standards. Instead, they recently issued radiation dose limits which apply to the dose received by the public as a result of airborne emissions from DOE facilities. Compliance with these new EPA standards will generally be based on dispersion calculations rather than through environmental measurements.

DOE:

As previously stated, DOE has established radiation dose standards for members of the public which must be met by DOE operations. Air concentration guides were derived in most cases from these standards and are also presented in DOE Order 5480.1. These guides are reduced by a factor of three when applied to a suitable sample of the population. These guides assume continuous exposure for 168 hours per week, 52 weeks per year; therefore, they are most meaningful when compared with annual average air concentrations. When a mixture of radionuclides are present, these guides must be adjusted so that the maximum individual and population exposures are within the prescribed limits.

TABLE 2

Isotope	Soluble/Insoluble	µCi/mL
U-234	S	2×10^{-11}
U-234	I	4×10^{-12}
U-235	S	2×10^{-11}
U-235	I	4×10^{-12}
U-238	S	3×10^{-11}
U-238	I	5×10^{-12}

NRC:

A licenseee shall not release radioactive materials to unrestricted area in concentrations which exceed the limits specified in Appendix B, Table II, (Code of Federal Regulations, Chapter 10, Part 20) except as noted below. Concentrations may be averaged over a period not greater than one year.

TABLE 3

(Appendix B Table II)

Isotope	Soluble/Insoluble	μCi/ML
U-234	S	2×10^{-11}
U-234	I	4×10^{-12}
U-235	S	2×10^{-11}
U-235	I	4×10^{-12}
U-238	S	3×10^{-12}
U-238	I	5×10^{-12}

A Licensee will be allowed to apply these same limits at the location of the maximally exposed individual if NRC is satisfied that the licensee has made a reasonable effort to minimize the radioactivity contained in effluents to unrestricted areas. (This exception is rarely granted.)

NRC may reduce licensee effluent limits if it is determined that a suitable sample of an exposed population group would be exposed to radioactive materials, through air, water or food intake, equivalent to that received from continuous exposure to air or water containing one-third of these concentrations.

EPA:

On January 17, 1985, the EPA published final rules (40CFR 61) for radionuclides in support of Clear Air Act National Emission Standards for Hazardous Air Pollutants. For existing sources the standards take effect 90 days after publication in the Federal Register. These standards limit radionuclide emissions from DOE facilities to an amount that causes a dose equivalent rate of 25 mrem/year to the whole body or a dose equivalent rate of 75 mrem/year to the critical organ of any member of the public. In addition, EPA will grant a waiver of these limits, if a facility operator demonstrates that no member of the public will receive a continuous exposure of more than 100 mrem/year effective dose equivalent and a noncontinuous exposure of more than 500 mrem/year effective dose equivalent from all sources, excluding natural background and medical procedures. (These latter provisions embody the recommendations of the National Council on Radiation Protection and Measurements for exposure to external radiation.) Compliance with the standard will be determined by calculating the dose to members of the public at the point of maximum annual air concentration in an unrestricted area where any member of the public resides or

III. Radioactivity in Water Standards/Guidelines

As in the case of air, DOE and NRC have concentration guides and maximum permissible concentrations, respectively. In practice, both are applied to the site boundary. Thus, the major difference is that one is a guide and the other a legally imposed limit.

EPA has issued drinking water standards for most radioactive materials, but not uranium. While these standards, as issued, apply to the quality of water when it reaches the user of a public water system, they are commonly adopted by states as surface water and groundwater quality standards, e.g., by water quality or hazardous waste organizations. When applied to surface waters, these standards usually apply to all portions of streams classified for drinking water use. Also, streams which have not been classified due to their small size are classified by default for all uses, including drinking water. Groundwaters are also classified for differing uses depending upon factors such as existing water quality and the amount of groundwater which can be pumped for use.

DOE:

The discussion regarding DOE air concentration guides applies to water concentration guides as well. These guides for water as shown in DOE Order 5480.1, are as follows:

TABLE 4

Isotope	Soluble/Insoluble	µCi/mL
U-234	S	4×10^{-6}
U-234	I	3×10^{-5}
U-235	S	4×10^{-6}
U-235	I	3×10^{-5}
U-238	S	6×10^{-7}
U-238	I	4×10^{-5}

It should be noted that DOE's soluble uranium numerical guides, since 1981, have been more restrictive than those previously in effect reflecting the use of more current data on the uptake of uranium through the gastrointestinal tract.

NRC:

A Licensee shall not release radioactive material to an unrestricted area in concentrations which exceed the limits specified in Appendix B, Table II, (Code of Federal Regulations, Chapter 10, Part 20) except as noted below. Concentrations may be averaged over a period not greater than one year.

TABLE 5

(Appendix B, Table II)

Isotope	Soluble/Insoluble	µCi/mL
U-234	S	3×10^{-5}
U-234	I	3×10^{-5}
U-235	S	3×10^{-5}
U-235	I	3×10^{-5}
U-238	S	4×10^{-5}
U-238	I	4×10^{-5}

A Licensee will be allowed to apply these same limits at the location of the maximally exposed individual if NRC is satisfied that the licensee has made a reasonable effort to minimize the radioactivity contained in effluents to unrestricted area. (This exception is rarely granted.)

NRC may reduce licensee effluent limits if it is determined that a suitable sample of an exposed population group would be exposed to radioactive materials through air, water, or food intake equivalent to that received from continuous exposure to air or water containing one-third of these concentrations.

EPA:

EPA has established drinking water standards that include many radionuclides, but not uranium. Nevertheless, the existence of these standards for other radionuclides is relevant to gaining a perspective as to the significance of uranium concentrations in water. Also, for the past few years, EPA has been evaluating an appropriate drinking water standard for uranium. This standard is presently expected to fall within a range of 10 - 40 picocuries per liter, which equates to 1.0×10^{-8} - 4.0×10^{-8} µCi/ML.

These EPA radiation standards, as promulgated in 40 CFR 141, apply in water which is delivered to the free flowing outlet of the ultimate user of a public water system.

IV. Radioactivity in Soil Guidelines

The NRC has established guidelines for uranium in soil in unrestricted areas. DOE's determinations are on a case-by-case basis. Experience to date shows both agencies to be using similar guidance.

DOE:

The Department of Energy's Formerly Utilized Sites Remedial Action Program establishes uranium soil clean-up criteria on a case-by-case basis in conjunction with the State agencies involved. Since potential land use will vary, small differences in clean-up criteria may result. To date, uranium criteria for unrestricted use have been in the 35 - 40 pCi/g range.

NRC:

The Nuclear Regulatory Commission has issued a Branch Technical Position on uranium in soil levels permissible for unrestricted use of property. These levels are as follows:

TABLE 6

Material	pCi/g
Depleted Uranium:	
Soluble	35
Insoluble	35
Enriched Uranium:	
Soluble	30
Insoluble	30

Miscellaneous Environmental Media

There are no specific standards or criteria in general use for uranium in sediments, vegetation, fish, or other edibles. Instead, acceptable levels would be determined on the basis of assuring that the applicable exposure limit is not exceeded through the sum of all pathways to individuals or to suitable samples of the exposed population.

In the case of sediments, clean-up criteria would be established using such factors as the likelihood of the sediment being used as topsoil, and its contribution to uranium reaching fish and their ultimate consumption by humans. Since the uptake of uranium in fish is very small, the first factor is normally of more relevance in establishing the need for remedial actions.

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